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Superresolution of Passive Millimeter-Wave Imaging

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6. AUTHOR(S)
Stanley J. Reeves

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Auburn University
Auburn, AL 36849-5201

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13. ABSTRACT *(Maximum 200 words)*

This project develops methods for image acquisition that will provide superresolution capability without the benefit of assumptions about the object intensity distribution. Superresolution is of particular interest in passive millimeter wave imaging, which has tremendous potential for imaging in adverse conditions but suffers from poor resolution.

Because of the finite aperture in PMMW, the acquired image is strictly bandlimited. Therefore, an important issue is sampling pattern optimization. Ordinarily, a focal plane sensor array has sensors placed in a rectangular grid pattern at sub-Nyquist density, and the must be dithered to sample the image plane at the Nyquist density in each dimension. However, the Nyquist density oversamples the image due to the usually circular support of the diffraction-limited image spectrum. We have developed an efficient algorithm for optimizing the dithering pattern so that the image can be reconstructed reliably from a less dense periodic nonuniform set of samples, which can be obtained from a dithered rectangular-grid array. The resulting algorithm can be used to explore image acquisition strategies.

We have also investigated optimizing the aperture sensitivity to shape the spatial frequency response of the acquisition system. Preliminary results indicate only marginal improvement. However, under certain circumstances, as in the case where edge detection is the primary task for imaging, more significant improvement may be achieved.

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Superresolution of Passive Millimeter-Wave Imaging
AFOSR Grant AF-F49620-98-1-0343
Final Report
Principal Investigator: Stanley J. Reeves, Associate Professor

Department of Electrical Engineering
Auburn University
Auburn, AL 36849

1. Objectives

This project further develops a new method for image acquisition that will provide superresolution capability without the benefit of assumptions about the object intensity distribution. Superresolution is of particular interest in passive millimeter wave imaging, which has tremendous potential for imaging in adverse conditions but suffers from poor resolution. By integrating higher powers of instantaneous intensity, higher spatial frequencies are recorded in the image plane. Through appropriate image processing strategies, the measured spatial frequencies can be extracted from the measured image in a postprocessing step to obtain a superresolved image. The processing strategy is dependent upon the statistical characteristics of the recorded image. Therefore, this effort requires an integration of work in statistical optical analysis and digital image processing.

2. Technical Accomplishments

Our work has focused primarily on sampling issues in the image plane. Because of the finite aperture in PMMW imaging, the acquired image is strictly bandlimited. Therefore, an important issue is the optimization of the sampling pattern. Ordinarily, a focal plane sensor array has sensors placed in a rectangular grid pattern at sub-Nyquist density, and the array must be dithered to sample the image plane at the Nyquist density in each dimension. However, the Nyquist density oversamples the image due to the usually circular support of the diffraction-limited image spectrum. We have developed an efficient algorithm for optimizing the dithering pattern so that the image can be reconstructed as reliably as possible from a less dense periodic nonuniform set of samples, which can be obtained from a dithered rectangular-grid array. Taking into account the circular frequency support of the image, we sequentially eliminate the least informative array recursively until the minimal number of arrays remain. We have also extended the algorithm in principle to sequential selection rather than sequential elimination. This may be more computationally attractive, and it is preferable to backward selection in that more potential dithered locations can be considered. The resulting algorithms can be used as a tool in exploring the optimal image acquisition strategy.

We have also investigated optimizing the aperture sensitivity to shape the spatial frequency response of the acquisition system. Preliminary results indicate only marginal improvement. However, under certain circumstances, as in the case where edge detection is the primary task for imaging, more significant improvement may be achieved.

3. Conclusions

The sampling time can be reduced below that dictated by the Nyquist

criterion in the case of dithered sub-Nyquist sensor arrays. This approach may also yield image data that is more amenable to superresolution. Other acquisition-related optimization strategies, such as weighting the aperture response, may also provide further improvements in superresolution potential.

4. Personnel Supported

Stanley J. Reeves, PI
Yun Gao, Graduate Research Assistant

5. Technical Publications

S. J. Reeves, "Superresolution imaging of non-Gaussian emitters," to appear in Signal Processing.

Y. Gao and S. J. Reeves, "Optimal dithering of focal plane arrays in passive millimeter-wave imaging," submitted to Optical Engineering.

Y. Gao and S. J. Reeves, "Optimal dithering of focal plane arrays in passive millimeter-wave imaging," in SPIE Vol. 4032 --- Passive Millimeter-Wave Imaging Technology IV (R. M. Smith and R. Appleby, eds.), (Orlando, FL), pp. 239--248, SPIE - Int. Soc. Opt. Eng. (US), April 2000.

Y. Gao and S. J. Reeves, ''Optimal sampling in array-based image formation,'' to appear in Proceedings of the 2000 IEEE International Conference on Image Processing.

6. Interactions/Transitions

Visit with AFRL personnel in the Seeker Technology Branch of the Munitions Directorate at Wright Lab, Eglin AFB, December 1999.

7. Patent Disclosures

None.